CHAMBERS-MCKEE WINDOW GLASS COMPANY
(American Window Glass Company)
(American Saint-Gobain)
(Jeannette Sheet Glass Company)
(GGI)
Clay Avenue Extension
Jeannette
Westmoreland County
Pennsylvania

HAER No. PA-221

HAER
PA
65-JEAN,
77-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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Historic American Engineering Record
National Park Service
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HISTORIC AMERICAN ENGINEERING RECORD

CHAMBERS-MCKEE WINDOW GLASS COMPANY
(American Window Glass Company)
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(Jeannette Sheet Glass Company)
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HAER No. PA-221

Location:	Jeannette, Westmoreland County, Pennsylvania
Date of Construction:	1888
Fabricator:	James Chambers, H. Sellers McKee
Present Owner:	GGI
Present Use:	closed (1993)
Significance:	The largest window glass factory in America when constructed in the late 1880s, the American Window Glass Company plant at Jeannette embodied the first three generations of window glass technology: the transition from artisanal production to Lubbers machine, and the replacement of Lubbers technology by Fourcault machinery. Until it closed, this was the last plant in North America using this technology.
Historian:	Richard O'Connor, August 1991

Project Information:

In February, 1987, the Historic American Engineering Record (HAER) and the Historic American Buildings Survey (HABS) began a multi-year historical and architectural documentation project in southwestern Pennsylvania. Carried out in conjunction with America's Industrial Heritage Project (AIHP), HAER undertook a comprehensive inventory of Westmoreland County to identify the region's surviving historic engineering works and industrial resources (Edward K. Muller and Ronald G. Carlisle, Westmoreland County, Pennsylvania: An Inventory of Historic Engineering and Industrial Sites. Washington, DC: U.S. Department of the Interior, 1994.) Archives for HAER/AIHP projects are located at the Indiana University of Pennsylvania.

CHRONOLOGY

1888	Chambers-McKee Window Glass Company built with first continuous melting tank in America
1891	James Chambers breaks with Sellers McKee and opens Chambers Window Glass Company in Arnold, Pennsylvania
1899	Chambers forms American Window Glass Company, absorbing Chambers-McKee and Chambers Window Glass Companies
1904	Lubbers cylinder-drawing machines installed, displacing skilled gatherers and blowers
1928	Fourcault sheet-drawing machines replace Lubbers cylinder-drawing machines
1958	American Saint-Gobain formed by merger of American Window Glass Company with Blue Ridge Glass Corporation, owned by Saint-Gobain of France
1970	renamed ASG
1978	Float, Inc. merges ASG and Fourco Glass to creat AFG
1983	AFG closes Jeannette plant
1985	Jeannette plant reopened as ESOP under name JSG (Jeannette Sheet Glass)
1987	JSG enters Chapter 11 bankruptcy
1989	General Glass International buys plant and renames it GGI (General Glass Industries)
1993	GGI closes Jeannette plant

Introduction

During the summer of 1991, the Historic American Engineering Record (HAER) conducted a three month study of the flat glass industry[1] at Jeannette, Pennsylvania, a community of ten thousand residents in Westmoreland County, approximately 30 miles east of Pittsburgh. Jeannette has been a "Glass City" for over a century, its workers turning out tablewares, containers and novelties in addition to window glass. At their peak, in the years immediately following World War II, the city's seven glass plants employed over 5000 men and women, but residents generally agree that incompetent and dishonest management squandered much of this industrial inheritance.[2] Until 1993, one of the two factories still in operation was the General Glass Industries (GGI) window glass factory, the most recent successor to the Chambers-McKee Window Glass Company (C-M), one of the town's first plants. GGI operated the last Fourcault sheet drawing process in North America.

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[1]Between 1889 and 1940, window glass was a subcategory of the flat glass branch of the glass industry, devoted primarily to providing glass for construction and furniture. On the basis of technology and markets, the industry was divided into two major branches, plate and window. Plate glass was cast, ground and polished in discrete operations, in thicknesses ranging from seven sixty-fourths of an inch to one and one-half inches. Its primary markets were automobiles, mirrors and tabletops, and storefronts. The second branch, and the subject of this study, was common window glass. Known as cylinder, crown and sheet glass (after various production processes,) by the early twentieth century window glass consisted of three types: thin glass (lantern, microscope and photographic dry plate glass); common window glass (window and door glazing); and crystal sheet (automobile replacement glass, show cases, table tops.) During the nineteenth century, and especially before the production of plate glass in America became commercially viable, residential, commercial and industrial glazing were the end uses, and the economic vitality of the window glass industry reflected the general health of the construction industry. <u>United States Tariff Commission, Flat Glass and Related Products</u>, 2nd Series, No. 123 Washington: GPO, 1937; p. 79.

[2]Steven W. Keller, "Working in 'the Glass City': The Making and Shattering of Jeannette, Pennsylvania, 1888-1991," Field Report submitted to Folklife Division, America's Industrial Heritage Project, Allegheny Highlands Heritage Center, Johnstown, PA, 1991.

The HAER documentation effort focused on three aspects of the window glass industry's historic legacy in Jeannette. Founded in 1888, C-M contained the first continuous melting tank furnace in the United States, a qualitative break from traditional pot and furnace melting technique. Rebuilt over twenty times since then, the tank stands today in the same place as the first one over a century ago. Second, each of the three different glass-shaping techniques used at Jeannette during the past century--the hand process (1888-1904); the Lubbers cylinder process (1904-1928); and Fourcault sheet machine process (1928-)--represents an era in the industry's technological history. The innovative continuous tank notwithstanding, Chambers-McKee still depended on skilled craftsmen to turn molten batch into lights of glass, and thus continued the industry's artisanal production traditions. In 1904, five years after Chambers-McKee joined the American Window Glass Company trust, the company replaced blowers and gatherers at Jeannette and the rest of its factories with the revolutionary Lubbers cylinder drawing process. It retained the cylinder process for nearly a quarter century before the superior quality and efficiency of sheet glass production confronted the AWGC with the difficult choice between bankruptcy or substituting sheet for cylinder machinery. The Fourcault machines installed in 1928 are still making glass today, albeit rebuilt and modified many times in the intervening years. Thus, from a historical perspective, the Jeannette window glass factory's technological significance rests on its innovations (continuous tank and Lubbers process), its persistence (Lubbers in the 1920s and Fourcault today), the variety of its technological experiences, and the site's current integrity.

The history of technological innovation at Jeannette complements the conventional wisdom on late nineteenth and early twentieth century American industrial development. During this period, historians argue,[3] a "second industrial revolution" spread from older manufacturing centers to their rural hinterlands, creating

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[3]Ronald Schatz and James Barrett place their studies of electrical and packinghouse workers in the context of a "second industrial revolution." Ronald Schatz, The Electrical Workers (Urbana, IL: Univ. of Illinois Press, 1983), pp. 3-4; and James R. Barrett, Work and Community in the Jungle (Urbana, IL: Univ. of Illinois Press, 1987), pp. 2-3. There is ample historical evidence to support the concept. See, for example, Harold G. Vatter, The Drive to Industrial Maturity (Westport, CT: Greenwood Press, 1975); Alfred Chandler, The Visible Hand (Cambridge, MA: Harvard University Press, 1977); and Martin J. Sklar, The Corporate Reconstruction of American Capitalism, 1890-1916 (Cambridge: Cambridge University Press, 1988).

satellite communities whose economic vitality came from new manufacturing industries like electrical equipment and automobiles, and from heat-using process industries like steel, glass and chemicals. Based on new sources of power--coal, coke, gas, oil and electricity, and more sophisticated technologies--industries of the "second industrial revolution" were more concentrated and their firms larger and better financed than others, railroads excepted. But what of the anomalies displayed by older industries like glass that were rapidly transforming themselves to the new model? Unlike electrical equipment, automobiles and telecommunications, glass was an old commodity with deeply ingrained artisanal production traditions, including a customary knowledge of its behavior and properties that was widely diffused among tradesmen but relatively unknown to the companies. Again, unlike the products of the newly developing industries, glass did not lend itself to laboratory experimentation because the greatest difficulties encountered in its manufacture occurred in the scale, volume and heat of factory production, conditions not easily replicated in the laboratory.[4] For glass and other older industries to join the "second industrial revolution," they too, like electrical equipment and chemicals, needed large amounts of capital and exploitable, patentable technologies. But they also had to overcome entrenched craft and entrepreneurial traditions that influenced their transformation in every respect.[5]

Background

Well into the 1880s, production of window glass took place much as it had for a century past. Still sensitive to the cost and availability of adequate fuel, manufacturers continued to locate and relocate in regions where coal and/or natural gas were plentiful, obtainable, and cheap, and near major transportation arteries. Increases in the scale of production and the division of labor notwithstanding, old manufacturing methods continued: batch was still melted in pots inside furnaces, and craftsmen

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[4]Liddell notes the difficulty of applying the results of laboratory experiments to factory conditions. Liddell, "Science," p. 128; on the other hand, Fourcault purportedly used hot wax and a small-scale model to demonstrate his sheet drawing process. Glass Industry, Vol. 2, No. 8 (August, 1921), pp. 190-1.

[5]Including traditions of secrecy and "the mutual distrust between glass men and scientists." Liddell, "Science," pp.114-23.

still shaped the viscous mass into lights of glass. The remarkable stability in firm size, technology and skill was both cause and effect of strong, deeply-rooted subcultures of workers and manufacturers, typified by family and financial linkages among firms and by the strength of kinship, custom and organization among workers. It was this nineteenth century world that the Chambers-McKee factory helped transform.[6]

Tremendous demand for fuel and transportation shaped the geography of production among heat-using process industries like glass. In America, continuous glass production dated from the eighteenth century. Small operations by later standards, the earliest sat adjacent abundant supplies of sand and wood in three well-defined regions--southern New Jersey, central New York State, and the Ohio River Valley from Pittsburgh to Wheeling. As the population spread west, Pittsburgh increasingly became the industry's center and, by the 1880s, its output nearly equaled that of all other regions combined.[7]

The technology, small batch production based on the broad knowledge and deft skills of the blower, proved remarkably durable. A ceramic product, glass is the highly viscous state of silica, salt, lime and trace ingredients after fusion under heat and subsequent cooling. Until the late nineteenth century, glass was melted in pots inside large, rectangular furnaces. Both pot

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[6]The following discussion of nineteenth century window glass production summarizes Richard O'Connor, "Cinderheads and Iron Lungs: Window-glass craftsmen and the Transformation of Workers' Control, 1880 - 1905," (Unpub. Diss., University of Pittsburgh, 1991); pp. 25-50, which contains fuller documentation. One of the best sources on nineteenth century glass industry is Joseph Weeks, Special Report on Glass, U.S. Census of Manufactures, 1880 (Washington, DC: GPO, 1883), passim. See also the two economic history classics on the American glass industry: Warren Candler Scoville, Revolution in Glassmaking (Cambridge: Harvard University Press, 1948), pp. 14-6, 30-84; and Pearce Davis, Development of the American Glass Industry (Cambridge: Harvard University Press, 1949), pp. 118-39; as well as Trevor Bain, "The Impact of Technological Change on the Flat Glass Industry and the Unions' Reactions to Change: Colonial Times to the Present" (Unpub. Ph.D. Dissertation, University of California at Berkeley, 1964), pp. 20-61, 153-211; and Dennis Zembala, "Machines in the Glasshouse: the Transformation of Work in the Glass Industry, 1820-1915" (Unpub. Ph.D. Dissertation, The George Washington University, 1984), pp. 64-66, 93-97, 132-60, 192-220.

[7]On glass regions, see O'Connnor, "Cinderheads," pp. 50-79.

and furnace size grew during the nineteenth century, but their design remained standard. Fire from beneath the furnace, fueled by charcoal or coal and drawn upward by a strong draft, reverberated off the crown and onto the open pots. Furnaces generally contained between eight and twelve pots, and each pot held enough glass to provide a day's work for a blower.[8]

Almost all window glass was made in family-owned firms or limited partnerships, companies founded on family capital with experience in making and marketing glass. James Chambers, a founder of Chambers-McKee and Jeannette, was the son of Alexander Chambers, founder of A.& D.H. Chambers in 1843, and Martha Wightman Chambers, the daughter of veteran Pittsburgh glassmaker Thomas Wightman. George Blair, Chambers' uncle (married to Caroline Wightman Blair), was a member of the Dithridge Glass Company, later the Fort Pitt Glass Company and the Pittsburg Lamp, Brass and Glass Company, which also located a large factory in Jeannette in the 1890s. Beside the glass firm, which he took over in the 1870s, James was also a partner in a Butler, Pennsylvania plate glass works with William Schmertz, son of Belle Vernon, Pennsylvania glassmaker Robert Schmertz. Such traditions of inter-marriage and joint business ventures had existed among the Pittsburgh glass manufacturing elite since the days of the Craigs, O'haras and McCullys in the early nineteenth century, and gave the region's glassmakers deep reservoirs of capital and experience,[9] and a near spiritual reverence for their industrial ancestry.[10]

The batch process and the small scale of family and partnership

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[8]A good discussion of nineteenth century pot-furnace operation oan be found in Weeks, Report, 1880, pp. 34-41.

[9]"Pioneers of the Glass Industry: Brief Biographical Sketch of the Life of Alexander Chambers," Magazine of Western History, Illustrated (February, 1886); obituaries of James Chambers, NGB, 4 March 1922, and C&GW, 4 March 1922; obituary of George Blair, NGB, 20 May 1911. Zembala notes other family lineages in "Machines...", pp. 72-77.

[10]The bottle and crown glass works of General O'hara in Pittsburgh "met with great success," wrote industrial historian Albert Bolles in 1878, "and it is in operation even at the present day, under the ownership of Thomas Wightman & Company, though, of course so enlarged and changed as to possess only the soul, and not the body, of the original works." Albert S. Bolles, Industrial History of the United States (Norwich, CT: the Henry Bill Publishing Company, 1878; p. 544.

enterprises constrained the size of window glass establishments. The vast majority of firms operated one or two ten-pot furnaces, although a very few had larger facilities. Robert Schmertz, for example, owned plants in Belle Vernon and Fayette City, Pennsylvania and one in Ohio. James Chambers, on the other hand, built additional factories near the original A.& D.H. Chambers works, as well as one in nearby McKeesport.[11] In both cases, the extension of facilities meant the duplication of operations with few economies of scale. Each of Chambers' Pittsburgh glass houses--the Upper, Middle and Lower--and the McKeesport factory, was built and acquired at different times and all were outfitted for the complete manufacture of glass.[12]

Techniques for fashioning lights of glass changed as little as the technology for melting the basic ingredients. The skilled blower, long the central figure in glass production, remained so throughout the nineteenth century. Until the 1850s in some places, blowers gathered their own glass on the end of the blowpipe, shaped it into a cylinder by alternately blowing, reheating, swinging and spinning the pipe and gob of "metal," cracked the cylinder off the pipe, split it lengthwise, reheated and flattened it into a large sheet, and cut it into lights of glass.[13] By 1880, a division of labor limited the blower to forming the cylinder, while new groups of tradesmen -- gatherers, flatteners and cutters -- performed the remaining processes.[14] Nonetheless, as Belle Vernon window glass manufacturer Robert

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[11]American Glass Worker, Directory of Glass Factories in the United States, 1885.

[12]The growth of the Chambers firm can be followed in three volumes by George Thurston: (Pittsburgh As It Is (Pittsburgh, PA: W.S. Haven, 1857); Pittsburgh and Allegheny in the Centennial Year (Pittsburgh, PA: A.A. Anderson, 1876); and Pittsburgh's Progress, Industries and Resources (Pittsburgh: A.A. Anderson, 1886).

[13]Excellent descriptions of the hand process can be found in: "Great American Industries," Harper's New Monthly Magazine, Vol. LXXXIX, No. 470, 1889, pp. 249-254; and Frank Gessner, "The American Glass Industry, Its History, Development and Present Economic Importance," Secretary of Internal Affairs, 1900: Part III: Report of the Bureau of Industrial Statistics (Harrisburg: 1901), pp. 14, 25-7.

[14]In addition to O'Connor, "Cinderheads...", pp. 25-50, also see Zembala, "Machines...", pp. 93-7, on the emergence of the division of labor in skilled window glass manufacture.

Schmertz told the 1880 census enumerator: "The strong-limbed, muscular, and powerful-lunged animal known as man is the best machine ever invented, and no improvement has been made since his introduction into the manufacture of window glass more than 300 years ago."[15]

Bonds of family and master-apprentice united glassworkers in a subculture enriched with its own language, trade rules and social hierarchy. By the 1880s, many Pittsburgh glass workers were second and third generation employed by the same glass maker.[16] Shop floor traditions extending back hundreds of years reserved apprenticeships for the male offspring of craftsmen; glassworkers codified these traditions into union bylaws permitting only "sons and brothers" of members to learn the four trades. Several generations might be employed by one manufacturer at the same time, as were three generations of Hammetts and Winters working at the factory of Samuel McKee in Pittsburgh in the 1890s. Workmates became family as custom, unless abrogated by union rule, usually permitted the transfer of apprentices to other masters, thus entrusting the vocational education of a son to someone other than the parent.[17] The trades' vernacular--cinderhead (blower), roller (cylinder), pipe (blowpipe), cowboard (heat shield for face), doghouse (charging end of tank), footbench (work space), and a variety of other terms--reflected the industry's long traditions, the craftsman's personalization of his work environment, and the exclusivity of the glassworking fraternity.

Driven by the bitter experiences of the depression of the 1870s, glass workers fashioned one of the Gilded Age's most powerful unions out of the nascent solidarities of family and trade. Following the depression, gatherers in Pittsburgh Knights of Labor Local Assembly 300 (LA 300) and blowers in LA 322 merged, retaining the LA 300 name in deference to its prior organization. Cutters in LA 305 joined in 1880, as did the independently organized flatteners. Securing high wages and exercising impressive job control locally, by 1884 LA 300 had organized every factory in the country. A strike by eastern district workers in 1882-3 and a lockout in the west in 1883-4 solidified

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[15]Weeks, Report, p. 102.

[16]NGB, 30 Jan. 1897.

[17]Additional apprentice information can be found in O'Connor, "Cinderheads...", pp. 91-100. Dennis Zembala also argues the importance of family connections among window glass workers, in "Machines," pp. 155-6.

the union's position, firmly established industry-wide bargaining, and made Pittsburgh wages and usages the industry standard. During the "golden age" of hand window-glass manufacture, roughly the decade and a half following the 1870s depression, Pittsburgh was the industry's center and its workers thoroughly controlled the union. But the migration of manufacturers in the late 1880s and 1890s to gas belts outside Pittsburgh (e.g., the Jeannette plant of Chambers-McKee) and as far west as Indiana dissipated that power and ultimately led to the union's fragmentation in 1897.[18]

Knowledge, skill, endurance and organization made possible high wages and social status. Among the best paid skilled workers in America, some, like "big ring, double-thick" blowers Jules Quertinmont, a Belgian, his English co-worker Sam Pearsall, or Thomas Unks, an American, earned as much as $600 per month in the early 1890s.[19] The far more numerous single-strength blowers made approximately one-fifth of that amount. Gatherers earned roughly sixty-five percent of blowers' wages, but it was commonly held that a double-strength gatherer made close to the wages of a single-strength blower. Blowers and gatherers paid snappers a percentage of their wages--usually about fourteen and ten percent, respectively.[20] When Pearsall's house burned to the ground in 1895, an inventory of the loss reflected the style in which such wages allowed the men to live: "two fine pianos, a number of pieces of artistic furniture, valuable oil paintings, (and) fancy articles of a costly nature...six gold watches, two diamond rings and a diamond pin..."[21]

LA 300, in turn, facilitated workers' control over the salient terms and conditions of their jobs. In a remarkable exercise of self-discipline designed to protect their economic and physical health, union members limited individual output (and, perforce, earnings) to 192 fifty-foot boxes of glass per four-week settlement. This worked out to forty-eight boxes per week, or approximately eight and one-half boxes per day. At the furnace,

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[18]On the origins and development of Local Assembly 300, see O'Connor, "Cinderheads," pp. 80-137; and Zembala, "Machines," pp. 149-59.

[19]C&GW, 17 Dec. 1921.

[20]LA 300, Seventh Convention, 1895, Proc., p. 32; Eighth Con., 1896, Proc., p. 30; C&GW, 8 September, 1900; NGB, 15 Sept., 1900.

[21]Jeannette Daily Dispatch, 22 Nov. 1895; (hereafter, JDD.)

they enforced these limits by restricting the production of rollers to seventy-two per day, or nine per hour, with the last roller of each hour's production blown not more than fifteen minutes before the end of the hour. Blowers and gatherers worked eight hour shifts, although cutters and flatteners toiled considerably longer. In addition to regulating output, craftsmen (through LA 300) legislated holidays, arbitrated grievances, and closely guarded their union's exclusivity by restricting apprenticeships and discouraging the immigration of foreign craftsmen.[22]

Relationships between the largest Pittsburgh manufacturers and the most powerful union leaders shaped industrial relations in window glass for two decades. The three successors to David Swearer, LA 300's first president, worked for Chambers either in Pittsburgh or in Jeannette, and had long familial connections to his firm. Chambers was particularly close to James Campbell, union president from 1886 until 1890, and even tried to win the support of powerful Pennsylvania Senator Matt Quay for Campbell's appointment as immigration inspector. Campbell, in return, arranged a clandestine contract settlement in 1887 that proved unpopular among many workers, helped Chambers recruit men for the new factory in Jeannette, and vigorously campaigned for pro-tariff Republican Harrison for the U.S. presidency in 1888. John Eberhart, Campbell's successor and another Chambers worker, arranged for the union to lend Chambers $50,000 during the 1890s depression. One consequence of these conditions--regionally concentrated industry and non-adversarial labor-management relations--was the absence of industrial conflict. The settlement following the 1883-4 lockout began annual contract negotiations between union officials and leading manufacturers that made window glass strike-free among the skilled trades for over a decade.[23]

By the 1890s, expanding markets, new fuel resources, advances in melting technology, and a restrictive urban manufacturing environment made production based on small firms, craft skills, and an old, stable technology increasingly untenable. Rising demand from renewed building activity and new construction methods and materials encouraged manufacturers to add capacity

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[22]O'Connor, "Cinderheads," pp. 110-137;U.S. Commissioner of Labor, Eleventh Special Report, Regulation and Restriction of Output (Washington, DC: GPO, 1904), pp. 599-624.

[23]On the operations of the "informal system of industrial relations", see O'Connor, "Cinderheads," pp. 159-166.

and induced other entrepreneurs to build new factories.[24] Natural gas discoveries in western Pennsylvania, Indiana, and Ohio provided a cleaner, cheaper and more efficient fuel alternative to coal.[25] Finally, shortages of space for expansion, rising taxes, and other difficulties induced glass-makers to look elsewhere when expanding or rebuilding their facilities. In short, the industry's continued corporate, geographic and technological stability were no longer assured.

James Chambers and Jeannette, Pennsylvania

No one was more acutely aware of the changing environment for window glass production than James Chambers. The son of Pittsburgh glass-maker Alexander Chambers, James had inherited the business from his father and uncle in the 1870s. Expanding it throughout the next decade, he added new buildings to existing southside Pittsburgh facilities, erected an entire new factory at nearby McKeesport, and installed state-of-the-art equipment, including an experimental round pot furnace, the first in the industry. Nonetheless, by the late 1880s, Chambers had exhausted his potential for growth in the immediate Pittsburgh vicinity and was attracted by the supposedly rich natural gas deposits[26] of nearby Westmoreland County. Gas was cheaper--free if you owned the well, did not deposit the sulphur residues of coal-fired furnaces, and burned hotter and cleaner than coal. The area had significant transportation advantages: the mainline of the Pennsylvania Railroad cut directly through it and there was ample flat space for sidings. Westmoreland County's proximity to Pittsburgh capital, labor and distribution networks gave it added

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[24]Scoville, <u>Revolution</u>, 257-62.

[25]Surprisingly, there is little information on the relationship between natural gas and the glass industry. See O'Connor, "Cinderheads," pp. 165-7; Scoville, <u>op. cit.</u>; Ellsworth Steel, "The Flint Glass Workers' Union in the Indiana Gas Belt and the Ohio Valley in the 1890s", <u>Indiana Magazine of History</u>, 50 (1954), pp. 229-50.

[26]By 1892, the Chambers-McKee Company had installed two gas producers to complement its natural gas wells, noting they were inadequate to fire its three large tanks. Compare Sanborn Map Company, Jeannette, Pennsylvania, 1889, with 1892 site drawing on wall of GGI boardroom, Jeannette, Pennsylvania.

appeal to manufacturers.[27]

Chambers and McKee took advantage of important batch-melting innovations developed by European manufacturers between 1850 and 1880. Chief among these was the continuous regenerative melting tank pioneered by Fredrich Siemens and his brothers in Germany and England. Their tank combined three important features. First, observing that the density of glass increased as the batch melted, Siemens designed a vessel that removed the purest and most thoroughly melted "metal" while exposing unmelted batch for further melting and refining. Second, they developed a method of regeneration that preheated incoming fuel and air, effecting large savings on fuel and obtaining substantially hotter temperatures. Third, based on his work in the melting of iron and steel, Fredrich Siemens applied the open hearth principle to glass making, especially the "free development of the flame...aimed...in such a way that neither the charged batch nor the crown and sidewalls of the furnace nor the port outlets were touched by the flame."[28] Although European glass makers had adopted the continuous tank in the 1870s, Chambers was the first to utilize it in this country. Travelling to Europe in 1887, he returned with plans for the Baudoux-Pagnoul variant of the Siemens furnace.[29]

The continuous tank held three principle advantages over the pot

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[27]The advantages of the Grapeville region are described in rich detail in the lead story of the Commoner and Glass Worker, 25 May, 1889 (hereafter C&GW).

[28]Gunther Stein, "History of the Tank Furnace," in R. Gunther, Glass-Melting Tank Furnaces (np, 1957); p. 196. The following discussion of the tank and factory layout is based on Richard O'Connor, "The 'Jeannette Affair' and Beyond: Technology, Immigration, and the Division of Labor in the American Window Glass Industry, 1880-1900," (Unpub. paper delivered at the Annual Conference of the Society for the History of Technology, October, 1991). Zembala discusses the continuous tank furnace in "Machines", pp. 182-213, but virtually ignores its introduction into the window glass industry in the United States.

[29]The two major types of continuous tanks available at the time, the Baudoux-Pagnoul and the Gobbe, differed primarily in delivery of the fire. The former carried the flame through ports in the tank sidewalls, while in the latter the ports opened into the furnace through the crown. Robert Linton, Glass," The Mineral Industry, Vol. VIII, (1889), pp. 252-3.

and furnace melting system. Unlike pot furnaces, where at least one-half the time was lost to cooling, settling, working and reheating, the tank heated the batch continuously. Glass quality improved with the tank, due to the higher and more uniform temperatures, and a constant level of metal for gathering. Similarly, the elimination of fluctuating temperatures enhanced furnace durability. With continuous charging, the tank reduced by one-half the number of men needed to charge and attend the melting operation. Probably its most significant advantage lay in the rationalization of the production process. Transforming a discrete into a continuous process, the tank made window glass production possible on a twenty-four basis for the first time.[30]

The factory's layout and organization of production were equally impressive. For the most part, in the flow of operations from melting the batch to shipping the finished glass, the new plant proved markedly efficient. Batch was unloaded into the batch storage house from a rail siding a short distance off the Pennsylvania Mainline Railroad. Once mixed, a narrow gauge overhead railroad transferred the batch of sand, lime, salt cake and trace ingredients to the furnace houses, where furnacemen charged it twenty-four hours per day. Gatherers and blowers shaped the molten glass into cylinders, and snappers capped them off (removed them from the pipe,) split them lengthwise, and transported them to the flattening house adjacent to the blow room. After flattening, annealing and dipping, the sheets were conveyed to the adjacent cutting house, where lights of the required size were cut and the glass was packed and shipped out by rail from a second siding.[31]

Utilizing continuous melting tank technology and a fully rationalized layout, the Chambers-McKee plant easily dwarfed all existing window glass production facilities in both capacity and output. The plant's seventeen buildings sat on thirty-five contiguous acres of land. The first tank (furnace #2), completed in 1889, held spaces for seventy-two blowers and the same number of gatherers, and also required sixteen flatteners and twenty-eight cutters. During the next two years, furnaces number four and three were built, necessitating an additional one-hundred and twenty blowers and gatherers, and proportional numbers of cutters and flatteners. By way of contrast, Chambers' Pittsburgh factories contained three furnaces and a total of twenty-six

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[30]Weeks, Report, pp. 35-6. Not everyone hailed the tank as a success. See Charles Colne, Glass and Glass Ware, Reoort of the Paris Exhibition, 1878 (n.p., 1879), p. 356.

[31]C&GW, 25 May 1889; Sanborn Map, 1891.

pots, approximately fourteen percent of the capacity of the new Jeannette plant.[32]

The tank and the sheer size of the factory held important implications for the organization of the labor process. In pot and furnace production, a blower and gatherer alone could perform all of the functions necessary in transforming the molten "metal" into glass cylinders. The layout of the tank factory, despite its rational organization, required that workers travel great distances in the performance of their normal duties. Moreover, continuous melting increased the pressure on blowers and gatherers for continuous cylinder production, removing most impediments heretofore preventing workers from meeting union-legislated production limits of forty-eight boxes single-strength glass (thirty-two boxes double-strength) per week. To meet output demands, blowers and gatherers hired helpers known as "snappers," who performed a wide variety of ancillary tasks--from assisting lifting and moving the pipe and ball of glass to capping-off and cracking-open the cylinder. The tank, in short, transformed the two-man to a three-man shop. Disputes over who was to pay snappers--workers or manufacturers--raged throughout the 1890s and figured prominently in the union's 1897 fragmentation.[33]

The Jeannette tank's demand for blowers and gatherers severely taxed the supply of skilled men, and efforts to find skilled men plunged LA 300 into a political imbroglio. Throughout the 1880s, the union tightened the supply of blowers and gatherers. While the number of apprenticeships diminished as officials bid up the price of labor at annual negotiations, the union worked vigorously to restrict the immigration of skilled workers. The industry's expansion in the late 1880s had already created shortages, but the continuous tank gave the scarcity of blowers and gatherers a new urgency. Worried that Chambers might recruit non-union men from Europe, union leaders themselves sought out workers from among the organized factories of England and Belgium. The solicitation of European workers angered members of Pittsburgh's labor movement employed in less-privileged industries, and the city's Trades Council launched an investigation leading to charges by the Justice Department that the union violated the Foran Act by importing foreign labor into the United States (a measure the union had promoted in 1883.) In

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[32] C&GW, 25 May 1889; American Glass Worker, Glass Factory Directory, December, 1885; C&GW, Glass Factory Directory, Dec., 1892.

[33] O'Connor, "Cinderheads", pp. 173-4.

what became known as the "Jeannette Affair," union leaders were acquitted of charges after a highly publicized trial, but the scandal's residual impact reverberated to the floor of Congress, where anti-tariff democrats led by Bynum of Indiana attacked pro-tariff union leaders like Campbell and their supporters in the legislature.[34]

In 1891, the Chambers and McKee interest disintegrated, underscoring both the uneasy partnership their venture represented and the cutthroat tendencies of Gilded Age industrialists. From the beginning, McKee controlled financial matters and Chambers attended to the factory's daily operations. Both were involved in intricate and widespread financial empires. McKee, a "traction magnate," owned controlling interests in street railways in Buffalo, New York and Pittsburgh, among other cities. Chambers' interests were closer to home and apparently more tenuous, involving the Standard Plate Glass Company in Butler, the Chartiers Valley Natural Gas Company, and several banks. In 1890, the collapse of the shoe manufacturing business of W.E. Schmertz compelled him to liquidate his interests in the Standard Plate Glass Company, in which he was a coinvestor. The failure of the Butler works financially strapped Chambers, and McKee seized the opportunity to force him out of the Jeannette concern.[35]

Chambers secured new backing and left Jeannette to start a window glass factory in nearby New Kensington, on the Allegheny River[36], well within the orbit of Pittsburgh capital and commerce. The new plant of the Chambers Window Glass Company mirrored his former Jeannette factory. Its three large continuous tanks and modern efficient layout gave Chambers a new power base in the industry. During the height of the 1890s depression, he used his plant's large capacity to bully other manufacturers into accepting his prices and terms for operating. He also organized a cartel of window glass manufacturers to drive down wage rates and rationalize production and distribution arrangements. Just as important, the new factory also provided him with an outlet for his technological precocity. It was no

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[34]Richard O'Connor, "The 'Jeannette Affair': Skilled Window Glass Workers and the Politics of Market Regulation," (unpublished paper, 1986.)

[35]JDD, 17 Dec. 1890.

[36]In 1896, the area of New Kensington in which the factory was located and where most of its workers lived became the borough of Arnold.

coincidence that John Lubbers, who had already moved from Pittsburgh to Jeannette with Chambers, soon followed him to New Kensington, where he developed new flattening and annealing ovens that incorporated revolutionary glass transporting devices.[37]

But even Chambers was unable to overcome structural problems confronting the industry. In particular, the continued reliance on hand production methods and the proliferation of plants in the gas belts of Indiana, Ohio and Northern Pennsylvania simultaneously created a severe shortage of skilled labor and drove down glass prices. The number of tank places more than doubled between 1890 and 1898, from 1406 to 2856, while best estimates suggest the availability of fewer than 2000 blowers at the turn of the century, leaving up to one-fifth of the industry's capacity idle. Demand for glass, meanwhile, had failed to keep pace with the expansion of capacity. The index of dollar volume for new construction was the same in 1898 as it was in 1890, and the wholesale price index for window glass had actually fallen four points in the same period. Clearly, the diverging trends of increasing capacity, falling prices, and growing man-power shortages called for dramatic solution.[38]

The American Window Glass Company

In 1899, at the start of the largest merger movement in American history, Chambers secured the backing of financiers from New York and Philadelphia to create the industry's first trust, the American Window Glass Company (AWGC). The merger brought together forty-one firms containing seventy percent of the industry's capacity. Like the Jeannette and Arnold factories of McKee and Chambers, most of those taken over by the AWGC utilized continuous melting tanks fueled by natural gas, making them the industry's most efficient and, in all likelihood, most profitable. The trust also sought control over distribution channels, granting exclusive marketing contracts to wholesalers and dealer (but prohibiting them from selling non-trust glass,) and arranging for plate glass giant Pittsburgh Plate Glass to distribute AWGC glass in New England.[39]

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[37]On the flattening oven, see Davis, Development, pp. 180-1; on the AGC, see Davis, Development, pp. 130-1; Scoville, Revolution, pp. 217-8; Bain, "Impact," p. 30; Zembala, "Machines", pp. 215-22; C&GW, 8 Feb., 1896; NGB, 1 Feb, 1896.

[38]O'Connor, "Cinderheads", pp. 218-225.

[39]Ibid., 217-20.

Despite low production costs, sophisticated melting technology, and an efficient, widespread distribution system, control over prices and wages eluded the AWGC. The continuing importance of skilled labor gave every manufacturer equal access to production technology. The ready availability of natural gas, the exuberance of town boomers and promoters in encouraging new factory construction, and a vibrant cooperative movement among skilled workers swelled the number of plants to its former level by the early twentieth century. By 1901, the AWGC's share of production capacity had diminished from seventy to fifty percent, and by 1903 had reached forty-three percent.[40]

Shortages of skilled labor plagued the AWGC, as they had Chambers when he first opened Jeannette. The widespread excess of capacity over labor supply was only part of the problem. In the trust's case, a general and deeply-felt animosity to the growing monopolization of American industry drove workers from AWGC factories and into those of its competitors. Simon Burns, president of Local Assembly 300 (LA 300), the union of skilled window glass workers, told the union's convention in 1899 that the purpose of the trust "is to crush competition, curtail production, curtail expenses and boom prices, create a surplus of labor and reduce" their wages.[41] The convention announced its intention "to exert all its power to smash the proposed trust."[42] Following through on the threat, LA 300 filed suits against the AWGC in Indiana and Pennsylvania, claiming that former owners violated terms of their charters when they sold out to the AWGC. The union's victory in one of the suits stalled but failed to deter the trust's formation. In more effective tactics, the union encouraged its members both to work for independent firms and to start cooperative plants. By January, 1900, shortages of blowers and gatherers prevented the trust from operating nearly twenty percent of its capacity.[43]

Ultimately, the pernicious scarcity of blowers and gatherers proved intractable, despite ingenious attempts at resolving it. In exchange for union officials using "all their influence and power to man all the factories of the AWGC," the trust offered Local Assembly 300 at least seven, if not nine, months work, the restarting of idle plants at Bridgeton, New Jersey and Elmira and

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[40]Scoville, Revolution, p. 222.

[41]LA 300, Proc. 9th Convention, 1899, p. 9.

[42]C&GW, 5 Aug. 1899.

[43]O'Connor, "Cinderheads", pp. 236-8.

Cleveland, New York, the payment of snappers, and 5000 shares of AWGC stock (which the company held, applying dividends toward an eventual purchase price of $30/share.) In one sense, Chambers merely formalized a relationship that had roots in the 1880s and earlier: he made the union a partner, giving the trust preference over independent plants in the hiring of skilled workers and putting it on a par with worker-owned cooperatives. Many members opposed the deal, denouncing the "drift toward one-man power" in union leadership and scolding officials for making members "virtually slaves to the American Window Glass Company." They also decried the snapper payment arrangements, claiming it would take control of hiring, firing and disciplining snappers from blowers and gatherers.[44] By 1902, however, the emergence of a competing union of blowers and gatherers prevented LA 300 from meeting its obligations to the trust, and the AWGC abrogated the agreement.[45]

The Lubbers Cylinder Machine

The failure of monopolization to resolve the vexing, intertwined issues of overcapacity and skilled labor shortages[46] fueled the quest for technological solutions.[47] Since the mid-1890s, Chambers and flattener-inventor John Lubbers had been engaged in clandestine research on a mechanical blowing machine. Constructing an experimental factory in Allegheny City, now Pittsburgh's Northside, they spent eight years and over a million dollars developing machinery that successfully transformed molten "metal" into clear glass. By 1901, Lubbers was able to draw

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[44]<u>C&GW</u>, 16 June, 1900; 30 June, 1900; 7 July, 1900; O'Connor, "Cinderheads," pp. 239-42.

[45]O'Connor, "Cinderheads", p. 257.

[46]According to Robert Linton, an engineer with the AWGC at the time, "(t)he company had been experiencing a serious and constantly shortage of blowers...," the result of union policies restricting apprenticeships (which persisted even during periods of labor fragmentation), and the industry's uncontrolled expansion in the natural gas regions. Linton, "Machine", p. 10.

[47]Mechanization in window glass lagged behind that of other branches of the glass industry, and behind large-scale industry in general. "...(T)he manufacture of glass, like most other ceramic industries, has been one of the last to feel the influence of modern science." Liddell, "Science", p. 118.

cylinders approximately eight to ten inches in diameter and five to six feet in length, almost exactly the size of average hand-blown cylinders. The following year, they leased the Alexandria, Indiana factory of the American Window Glass Company, equipped it with twelve machines and continued their experiments, finally increasing cylinder size to eighteen feet in length, although developmental costs now aggregated over 2.5 million dollars. Still far from perfection, the Lubbers machine worked well enough for the AWGC to begin installing it in its factories in 1902. By 1907, the trust operated seven factories with machines and had closed its remaining plants.[48]

Inspiration and motivation for the machine's development also came directly from the control over production exerted by skilled workers. The patent courts recognized this most clearly. In his overall evaluation of the Lubbers patents, Judge Thomson concluded that "(t)he basic patents sustained in this action created a new art, set on foot a vast industry, reduced the price of window glass to a wide class of purchasers, and freed the art from the baleful grip of the hand-blowers union."[49] Similarly, in a separate suit argued in Federal Court in the Eastern District of Oklahoma, Judge Pollock noted that the purpose of the Lubbers experiments was to produce "cylinders of the length, the thickness, the diameter, and the freedom from flaws and defects required to successfully compete in practical operation with the work and skill theretofore always employed by members of the glass blowers trade." But, he went on, "the necessity that mothered the inventive genius employed in this work was to escape the alleged tyranny of what is commonly known as the glass blowers' union, said to be one of the oldest and perhaps the most perfectly unified bodies of skilled workmen known to this or any other age or country."[50]

The design and organization of Lubbers' machine process reflected his long connection with the glass industry and the imprint of its centuries-old labor process on his technical vision. A flattener by trade, Lubbers had worked for Chambers since the late 1870s, first in his Pittsburgh factories, then in Jeannette, and finally in New Kensington. During his twenty years of work experience in hand factories, skilled blowers and gatherers had dominated the production process. Hand production of lights of window glass involved the preliminary steps of making a glass

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[48]inton, "Machine", pp. 9-10; NGB, 23 Nov., 1918.

[49]NGB, 30 Nov., 1918.

[50]NGB, 2 Nov., 1918.

cylinder that required flattening and cutting into requisite sizes. Lubbers' machine process operated in the same fashion. Molten "metal" was first ladled from the continuous tank into a heated pot. A "bait" was then lowered into the pool of pot," remaining long enough for the metal to adhere to its flanged rim. The bait was raised slowly while air was simultaneously pumped into the growing cylinder. When it had reached the designated height, the cylinder was broken off, laid horizontal, and cut into sections (shawls) for flattening. In short, the Lubbers process replicated the counter-intuitive procedure of the hand process: making flat sheets of glass required the prior step of making cylinders.[51]

Glass makers lacked scientific knowledge about the behavior of glass, particularly under conditions of large-scale production. For centuries, knowledge and skill in the glass industry belonged to a small circle of families, passed from generation to generation in great secrecy. By the late nineteenth century, a de facto division of responsibility had evolved between, on the one hand, window glass owners and managers who watched over and carefully guarded glass formulas and financial records, and skilled tradesmen on the other, who developed, honed and controlled the acquisition and employment of the knowledge and skills of shaping molten glass. In the context of family-owned firms and generations of tradesmen there existed a general hostility to the scientific study of the principles of glass-making.[52] Moreover, throughout American industry, industrial research--the application of scientific principles to the production of industrial goods--was in its infancy in the early years of the twentieth century. Thus, to John Lubbers fell the full range of tasks from the discovery of scientific principles to their industrial implementation. His position was all the more difficult because, as a flattener, he lacked the intuitive knowledge and skills of the blower and gatherer, who spent their working lives in the searing heat of the furnace deftly manipulating molten glass.

Since the company already utilized the continuous tank exclusively, the technical starting point for machine development was the constellation of glass working knowledge and practices passed down by craftsmen through the centuries. Tools and devices such as floating rings and blowpipes had long existed in

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[51]For Linton, the fact that cylinders made by the Lubbers' process "were in every respect similar to those that were blown by hand" was a source of pride. Linton, "Machine", p. 7.

[52]Liddell, "Science", pp. 116-22.

the hand industry. The tank itself, developed and perfected during the late nineteenth century, at first required little modification to accommodate the new machines, although as cylinder size increased, the tanks were "remodeled--not enlarged, or only slightly enlarged...," according to Linton.[53] For salient first principles regarding cylinder expansion and elongation, however, Lubbers, Chambers and the AWGC looked to the techniques of skilled workers. As U.S. patent judge W.H.S. Thomson noted: "...the hand blower maintains a uniform diameter by increasing the swing, with the resulting increase in the pull. This principle he knew well and practiced constantly, just as he knew that increasing air pressure within the cylinder was necessary to maintain a uniform diameter as the cylinder lengthened. Upon these two principles the art of hand blowing glass cylinders was so largely built..." In short, Thomson concluded in disallowing several claims of the AWGC, "(t)hose who attempted to do by machinery what the hand-blower had done successfully for generations, presumptively knew the fundamental principles upon which the art had been built."[54] Indeed, defendants sued by the AWGC for patent infringement argued that such patents were "invalid because anticipated by the prior state of the art...."[55]

The set of mechanical operations transforming molten metal into cylinders of clear glass was not a single machine but a group of individual devices linked sequentially to constitute a "process," a critical distinction emphasized in later patent suits. Judge J. Pollock stressed that "each patent involved in this suit leans for its validity and strength upon others...." After "spending many days in an endeavor to disengage a single patent from all others in order to give the claims thereof separate consideration, as is usually done in the investigation of claims of patents put in issue," he ultimately had to view "the entire process as worked out to completion through the many steps taken therein, regarding each step taken by plaintiff, or those under whom they claim, attempted to have been covered by a separate patent containing nothing both new and useful in itself, but new and useful, or the contrary, only in combination with the other

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[53]Linton noted that "(t)he maximum amount of glass gathered in 24 hours from (a tank) under hand operations was 3.7% of the total contents of the tank, while under machine operations more than 20% has been ladled from the same tank in 24 hours." Linton, "Machines", pp. 13, 21.

[54]NGB, 30 November, 1918.

[55]NGB, 2 Nov., 1918.

steps taken in conjunction therewith." Emphasizing process over individual inventions conferred privileged status on the machines. In overcoming the variety of problems encountered along the way, Judge Pollock reasoned, "either a new machine was designed to suit the purpose or a machine old in principle was adopted to accomplish the new purpose to which theretofore it had not been applied. In either event a new and useful result was accomplished theretofore unknown and unused in the art." Thus, the process itself received the basic patent, thereby giving the patent courts much latitude in defending claims of the patentee on individual devices, which it did in numerous suits between 1914 and the mid-1920s.[56]

Despite the rich legacy of the hand industry, critical aspects of the cylinder process developed by Lubbers, Chambers, Thornburg, Hitner and others neither formed part of the "prior art" of glass blowing by hand nor were anticipated by the unsuccessful attempts of previous inventors. In short, they were true innovations.[57] The patent courts noted with precision the salient differences between hand and machine processes:

> In the hand method, the ball of glass on the blow-pipe is made up of successive layers, each layer being chilled before the next is applied. The ball is a plastic solid differing much in temperature from the molten bath, is shaped before the draw is started, and has a heavy outer skin or layer. Instead of the cylinder being drawn upward from the stationary mass of molten glass, the glass is drawn away from the blow-pipe by its weight and the centrifugal force caused by the swinging of the cylinder. The operations are not continuous, but intermittent and successive, elongating by swinging, swelling the cylinder out, re-heating, blowing by puffs, etc. The problems of the liquid bath with its varying temperatures and surface tension, the differing zones of glass passing through the meniscus zone, the plastic zone, the setting zone, to the cold zone, all these are wanting in the hand-blowing process.[58]

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[56]NGB, 2 November, 1918.

[57]Robert Linton credited Lubbers with inventing "a process that took into account the peculiar conditions involved in working molten glass, and apparatus that actually made glass cylinders. Linton, "Machinery", p. 7.

[58]NGB, 23 Nov., 1918.

The litmus test for the validity of prior inventive efforts was their success. Reviewing the failures of earlier inventors--Loup in France (1856), Clark in Great Britain (1857), Frank in the United States (1883) and Opperman in Germany (1885)--Judge Pollock argued that "it may be accepted as a general truth that if they resulted in no practical development they lacked some element which the successful patent they are alleged to anticipate possessed."[59]

But poor market conditions and costs for machine development and plant changeover placed heavy financial burdens on the AWGC that it met with little success. The company's 1910 annual report, its first since 1902, noted that during the intervening period, "had our true financial condition been published there is no doubt but that the hand blowing manufacturers...would have compelled this company to suffer losses on the sale of its product it could not afford." The AWGC took loans from officers to pay for materials and wages. It also established a new corporate entity, the American Window Glass Machine Company, capitalized with $20 million of common and preferred stock. Of this amount, seven million dollars paid for patent and thirteen million dollars for all AWGC common stock. Owning both the patents and the AWGC, the Machine Company leased the process exclusively to the AWGC.[60] In 1904, the financiers took charge, secretly buying large blocks of stock (much of it purportedly belonging to John Lubbers) and ousting Chambers, general superintendent William Loeffler and manager George Moore.[61] The ascent of the money-men focused new attention on cost and accountability.[62] "Last January (1904) there was an absolute lack of system and organization," noted an internal AWGC report issued early in 1905.

> Everything was conducted on a most extravagant basis. Factory and office had to be reorganized from top to bottom. There was no proper cost system and so system of reports from the factories by which it could be known from day to day what they were doing....Instead of our former high standard of quality much glass was being packed that should not have been packed, being too thin and of an inferior

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[59]NGB, 2 Nov., 1918.

[60]Efficiency Investigation, (3), Analysis, p. 7.

[61]C&GW, 22 Oct. 1910.

[62]This was part of a general pattern in the evolution of the modern corporation. see Chandler, Nelson, et al.

> quality, which gave us a very bad name in the market. Many users absolutely refused to touch machine-made glass. In addition to this we had a large amount of "C" glass which at that time we thought almost impossible to dispose of.[63]

In addition to management personnel changes, they implemented a cost system with its plethora of attendant reports and concentrated on upgrading the quality of machine-made glass. From its formation in 1899 until 1919, the AWGC paid common stock dividends of one and one-half percent in only six quarters--all prior to the machine's installation.[64]

Reflecting the replacement of entrepreneurs by financiers in the company's management and lingering doubts as to the effectiveness of their expensive experiment, after 1905, the AWGC conducted numerous cost comparisons between hand and machine production, with reports underscoring the cost-effectiveness of machine technology. The company still maintained one factory on the hand method, #14 at Belle Vernon, Pennsylvania, and compared figures from that plant as well as historic pre-machine data from 1900--1904 from other AWGC factories with the output and cost figures from its machine-equipped plants. The earliest such study, carried out in 1904, revealed the cost of hand-produced glass to be approximately thirty cents per box more than that made by machine; by 1906, those figures had jumped to thirty-eight cents per box (single-strength) and twenty-nine cents per box (double strength.) Savings came primarily from the replacement of skilled craftsmen with semi- and unskilled machine workers. In place of blowers, gatherers and snappers, the company now employed a small army of ladlers, blowers (machine operators,) pot-turners, takers-down, cappers, crackers, small ladlers, pipe heaters, cullet wheelers, machinists and electricians. For the last settlement of 1906, wages paid blowers, gatherers and snappers were approximately sixty-seven percent higher than those paid machine labor. It comes as little surprise that, under machine production, cost per box plummeted even as the number of

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[63]Internal document, American Window Glass Company, January 24, 1905. Located in GGI Archives, untitled box.

[64]That the company did pay preferred dividends from 1 Nov. 1913 until 6 Oct. 1915 substantially higher than its usual three and one-half percent suggests whatever level of profitability machine operation had reached was devoted to equity payments. American Window Glass Co., Dividends Paid. (GGI misc. records.)

workers rose.[65]

These studies apparently convinced AWGC officials to slash both the size and earnings of machine crews. Reorganizing jobs at its Jeannette plant, the AWGC dispensed with one batch filler-in on each tank; 2 cullet wheelers from tank #2; twelve takers-down from tank #2; five pot-turners; two boss ladlers; two air men; and assorted extra machine labor. Wage cuts came in two forms. In some cases they were direct, as in the reductions for blowers (machine operators) and cappers by one-third, from 4-5/12 cents per box to three cents per box, and takers-down, from 5-2/3 cents per box to four cents per box. Particularly in the flattening house, the company also masked wage cuts by shifting hourly or weekly wages to piece rates. Shove-boys went from twenty cents per hour to 2-3/4 cents per box, while lehr tenders went from $11.85 per week to three cents per box. Figures for the impact of these reductions on workers' take home pay are not available. For the two years 1904-6, the AWGC estimated its weekly savings company-wide at $5,068, or 8.2 cents per box; at the Jeannette plant, crew changes and wage reductions yielded savings greater than the company average for all its plants: $1789.71 per week, or 10.3 cents per box.[66]

The company's most pressing problem, especially in the early years of machine production, was the failure of machine glass to match in quality or variety that produced by traditional hand techniques. Linton suggested that the decision to eliminate completely the hand process from AWGC plants and to rely fully on cylinder machines may have been premature.[67] Breakage sometimes

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[65]"Comparison of Cost of Machine and Hand Blown Glass, 1905;" "Comparison of Labor at Hand Factories with Machine Factories based on Production of American Window Glass Factories for settlement of December 28th, 1906."

[66]"Summary of Savings made at Factories," AWGC archives, 18 April, 1906.

Robert Linton estimated in 1917 that "the whole labor force of a present day machine blowing room is less than half the labor force in the blowing room of a hand operated plant." Linton, "Machine", p. 21.

[67]"...(I)t would naturally be expected that the difficulties that stood in the way of success would be overcome in the shortest possible time. As a matter of fact, however, they proved more serious than was appreciated, and the work of developing and improving the various parts of the apparatus continued for about two years longer, before satisfactory results

ran as high as eighty percent and the company lost money.[68] Early engineering efforts focused on improving the technology's ability to make large quantities of good quality, uniform, single-strength glass; the flexibility necessary to make a variety of thicknesses came later. Flaws in the glass itself, especially ripples from hot drawing temperatures, uneven or unsteady air supply, as well as the perennial problem of "thick and thin" glass, made large sizes impossible and diminished the AWGC's presence in the market for good-quality small sizes. Double-strength glass proved elusive until the pre-World War I years. Solving the worst of these problems, the AWGC's market share, consisting overwhelmingly of average quality, single-strength small sizes, climbed rapidly from twenty-five percent in 1906 to nearly sixty percent the following fire, and finally levelled off at approximately fifty percent by 1910.[69]

Lubbers technology gave the AWGC influence (but not control) over window glass production and distribution patterns. **Table 1** demonstrates the machine's impact on the industry during the early years of mechanization. Despite a forty percent decline in the number of hand plants after 1904, the year the AWGC introduced the Lubbers process, the sector nevertheless retained a fifty percent market share. Only the most efficient firms survived; pot furnace production, which had declined steadily since the 1890s, was all but eliminated by 1912.[70]

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began to be obtained." Linton, "Machine", p. 11.

[68]NGB, 23 Nov., 1918.

[69]Linton, p. 10; NGB., 6 Jan., 1906, 25 Oct., 1913; C&GW, 11 May 1907.

[70]To a large extent, these were cooperative enterprises located in the gasbelts. Many had started in Indiana in the 1890s or in West Virginia in the early years of the twentieth century. If the competition from the continuous tank and the Lubbers process did not kill them, then the strains of cooperation or the depletion of natural gas supplies did. For more on the formation of the cooperatives, see O'Connor, "Cinderheads, pp. 227-33.

Table 1

Year	Plants	Pots	Places (tank)	Places (total)	Machine Plants
1899	102	934	1920	2854	0
1900	100	858	1980	2838	0
1904	102	736	1557	2293	10
1905	99	510	2009	2519	10
1907	89	116	2837	2953	8
1908	79	84	2639	2723	9
1909	71	56	2337	2393	10
1910	64	32	2223	2255	10
1911	67	28	2353	2381	11
1912	59	0	2203	2203	10

Source: Commoner and Glass Worker Pub. Co., Factory Directories, 1899 - 1912

The hand sector persisted, as **Table 1** suggests, despite AWGC efforts to drive it under. Both prior to and following the introduction of Lubbers technology, the AWGC used its wide distribution channels and massive output potential to manipulate glass prices as a matter of corporate policy. As **Appendix A** illustrates, in the five years prior to the machine's introduction in 1904, single-strength glass sold for an average of $2.13 per fifty foot box. Between 1904 and 1912, this dropped to an average of $1.73, a price decline of nineteen percent, and reached its nadir at $1.47 per fifty foot box in 1912. **Appendix A** does not reflect the brief but powerful impact of the company's periodic price reductions, guarantees against further declines, and glass dumping.[71] Designed to reduce the demand for skilled labor in the years prior to the machine, after 1905 the AWGC used reductions to eliminate competition in the hand sector. The Commoner and Glass Worker noted that the AWGC price cuts were "a bitter pill for hand operators, since (the cuts) place(d) them in a position where they (had to) get their glass made at starvation wages if they expect(ed) to turn a profit."[72]

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[71]"Guarantees against further declines" refers to a practice of stimulating demand by announcing a price for glass and then promising to pass on any reductions over the course of a subsequent time period.

[72]C&GW, 2 Feb., 1908 (also quoted in O'Connor, "Cinderheads", p. 268.)

Skilled workers in the hand sector, (blowers and gatherers in particular), and not manufacturers, subsidized the AWGC's market prowess with reduced wage rates, fewer months of work, and declining job opportunities. Across all trades wages declined steadily after 1905 with but few interruptions. The emergence of competing unions in an overcrowded industry, led skilled workers to disregard published, negotiated wage rates in favor of "private agreements" with manufacturers that reduced the price of labor to near subsistence levels. Wage reductions fell disproportionately on blowers and gatherers, since wages and working conditions of flatteners and cutters, trades employed in both hand and machine plants, did not (and could not) differ significantly from sector to sector. The introduction of the machine led to renewed union solidarity among those in the hand sector and to the introduction of the sliding scale, the first since it was tried briefly in the early 1880s. The "sliding scale," according to one trade journal, put "the pay of 'cinderheads' (blowers) in many instances on a par with common labor..."[73] By 1911, wages for blowers and gatherers had fallen low enough to drive hundreds of men from the industry, creating an acute labor shortage.[74]

In addition to wages, conditions and hours of labor also suffered. Production seasons declined, with union legislated seasons of ten months per year in 1879 and nine months annually thereafter rarely lasting five months by the early twentieth century. The number of skilled jobs fell as the machine relegated blowers and gatherers to the shrinking hand sector. From 8500 available snapping, gathering and blowing places in 1899, 6600 remained in 1912, a drop of approximately twenty-three percent. Declining job opportunities eroded self-imposed limits on production, a longstanding measure considered the bulwark of craft power. Unions formally removed box limits at the Cedar Point wage negotiations in 1904, the same year the AWGC began turning out machine-produced glass. Wholesaler and manufacturer J.R. Johnston claimed "the Cedar Point scale offer(ed) the only opportunity to check the stride of the machine."[75]

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[73]NGB, 10 April 1909.

[74]Scoville notes in more detail the fluctuations in skilled window glass workers' wages. Scoville, Revolution, pp. 226-7, n. 107.

[75]NGB, 24 Dec. 1904; C&GW, 24 Dec., 1904; 14 Oct., 1905. It is questionable how much of an advantage this was for manufacturers. There is some evidence that craftsmen rarely produced to the limit even under the best conditions. Moreover,

The decline in wages and conditions were closely tied to trends in the number of available blowers' places, which in turn paralleled stages in the technology's development between 1904 and 1912. As **Table 1** (above) indicates, in 1905 the number of blowers' places plummeted when the AWGC closed its hand plants, changing-over and reopening ten as machine factories. The numbers grew in 1906 and 1907 when the machine proved incapable of making high quality, large size and double-strength glass, but then fell precipitously after intensive research and engineering efforts improved glass quality and provided machine technology greater flexibility in turning out glass of varying sizes and thicknesses.

In the light of new and powerful market forces, skilled workers refashioned their unions. Between 1880 and 1897, blowers, gatherers, flatteners and cutters belonged to Local Assembly 300, Knights of Labor. One of the strongest labor organizations of the period, LA 300 unilaterally set work rules and negotiated wages with manufacturers throughout the industry. The union fractured along geographic, ethnic and trade lines in 1897, spawning an array of competing organizations headed by strong personalities. Chaos reigned among unions until the machine's introduction in 1904, when the vast majority of blowers and gatherers formed the United Window Glass Workers, becoming the Amalgamated Window Glass Workers the following year and the National Window Glass Workers in 1908 (which lasted until the demise of the hand industry in 1928.) The new unions reflected the increasing craft and sector orientation of their members. Unlike Local Assembly 300 in the golden years of the Knights of Labor, which took a leading role in the broader social and cultural aspects of working class life, the unions of skilled window glass workers in the first decade of the twentieth century looked inward, concerned with the bread and butter issues of pure and simple trades unionism.

Although cutters and flatteners, unlike blowers and gatherers, remained essential to the production process in both sectors, they faced new conditions and circumstances. Wherever they worked, their labor grew more difficult. In hand plants an emphasis on increasing productivity meant more boxes to flatten and cut and, for cutters, more cuts per box. Machine plant flatteners found that the bigger shawls required more care, while higher melting and shaping temperatures in the machine process resulted in harder glass that was more difficult for cutters to cut. The overwhelming presence of the AWGC destroyed any pretence of parity between flatteners and cutters in the two

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any push for quantity often sacrificed quality.

sectors. The machine company offered regular work while men in hand plants could rarely depend on more than five or six months per year, and it sometimes paid higher wages than the hand sector could afford, either to attract sufficient workmen or as a tactic against hand manufacturers. Those working for the AWGC found the company a tough task master. In 1900 and again in 1909 flatteners and cutters struck the company over recognition and wage issues. Both times they lost and both times their union was nearly destroyed.[76]

Just as it restructured the industry, the Lubbers cylinder process transformed economic and social conditions in American Window Glass Company communities. Even the best paid machine worker earned less than the worst paid gatherer in pre-machine days, and there were far fewer well-paid machine workers than gatherers in each plant. Moreover, machine operators tended to be either native-born snappers from the hand sector or men from the new immigrant groups, particularly Italians; gone was the heavy concentration of Belgians predominating in the ranks of blowers and gatherers.[77] The unprecedented demand for residence hotels in Jeannette after 1904 reflected the attraction of recently-arrived single men to the machine plant, the slightly greater number of workers in the new process, and their lower wages.[78]

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[76]O'Connor, "Cinderheads", pp. 273-4

[77]Noted the Commissioner of Labor: "Following the introduction of machinery in 1904, all of the Belgians except those who owned property, left Jeannette to seek employment in other communities where the work was done by hand. Americans were placed on the machines, the introduction of which meant a large increase in the numbers of unskilled and semiskilled workmen. The lower occupations were filled by Italians and Poles and Slovaks." Immigration Commission, Reports: Immigrants in Industries, Part 12: Glass Manufacture, (Washington, DC: GPO, 1911; p. 33

[78]C&GW, 1 Jan. 1916; NGB, 26 Sept., 1903. We should also note that many Belgians had left Jeannette to work in cooperatives, such as the crew that accompanied Jules Quertinmont to Pt. Marion in 1899.

The Decline of Lubbers and the Rise of Fourcault

Improvements to the Lubbers process notwithstanding, eroding market share soon cooled the already tepid success enjoyed by the AWGC after resolving its most serious technical problems. By 1913, the company had applied for twenty-nine patents for various operations and devices associated with the cylinder drawing process; steadily improved the quality of its glass; and had become the industry's acknowledged price setter.[79] Instead of improving, however, its percentage of domestic production peaked at fifty percent annually between 1908 and 1912, then dropped to forty-six percent in 1913 and thirty-seven percent in 1914.

The company lost market share not to the hand sector but to an emerging panoply of "iron lungs."[80] The first successful mechanical competitors to the Lubbers process were little more than minor variations on the theme of cylinder production. By 1914, sixteen companies operated five different machines and produced a quarter of all domestically produced window glass. Pittsburgh Plate Glass ran twenty-four machines of its own design at the former Chambers factory at Mt. Vernon, Ohio, leased twenty-four machines to the United States Window Glass Company at Morgantown, and in 1915 lit the fires at a brand new plant at Clarksburg, West Virginia, with yet another twenty-four machines. Eight companies leased the machine of the Consolidated Machine Company of Bradford, Pennsylvania. Developed by M.J. Healy from patents of an inventor named Bolin issued as far back as 1906, the Consolidated machine required almost eight years of experimentation. To recoup its investment quickly and with minimal risk once its machine was a success, the company launched a vigorous campaign in 1914 to lease fifty machines to former hand manufacturers. Like the AWGC, it leased its machines to a subsidiary, the Consolidated Window Glass Company of Bradford, Pennsylvania; unlike the AWGC, it also sought out other clients.[81] The Camp Glass Company at Huntington, West Virginia

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[79]A.H. Tackett, "Interview with J.R. Johnston", Efficiency Investigation, 28 and 29 August 1914. Record Group No. 122, Federal Trade Commission, Bureau of Corporations, Numerical Files, 1903-14: No. 7077-4-1, Box No. 820. (National Archives)

[80]The hand sector found its own market share reduced to thirty-seven percent.

[81]Companies leasing the Consolidated Machine were: The Pennsylvania Window Glass Co., and the Kane Window Glass Co., both of Kane, PA; the Wichita Falls Window Glass Co. of Wichita Falls, Texas, the West Fork Glass Company and the Tuna Glass

used machines developed by Thomas Camp on two of its tanks, while its third ran under the hand process (reportedly the largest in the country to do so.) Two other glass makers also used Camp machines. The Okmulgee Window Glass Company at Okmulgee, Oklahoma ran twelve machines of its own design. Still more cylinder machines, such as the Frink and the Douchamp-Henshaw, were nearing implementation.[82]

Cross-fertilization of top technical personnel among machine companies helped diffuse the new technology. As the first and largest machine operation, the AWGC was a training ground for inventor and mechanic alike. Following the company's restructuring in 1904, many of its top glass men left to work with competitors. Chiding the AWGC's claim of "continuous lack of knowledge" of Pittsburgh Plate Glass' machine progress, Judge W.H. Thomson noted, "from the time the Mount Vernon (Ohio) plant was built (the Chambers factory, constructed in 1906) until the summer of 1914 there was a frequent exchange of workmen between the American Company's factories and those of" Pittsburgh Plate Glass, "and that during the period in question there were thirty or forty men who went from the Mount Vernon factory to the various factories of the American Window Glass Company." Among former AWGC men now working closely with the company's largest potential competitor were Chambers himself and Harry Slingluff, longtime Chambers employe who once managed the Jeannette AWGC plant.[83]

The AWGC aggressively defended its patent monopoly in the courts. Between 1907 and 1924, the company filed more than twenty patent

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Company, both of Clarksburg, and the Crescent Window Glass Company at Weston, West Virginia. One condition of the lease was that the Consolidated Machine Company sell all the glass of its machine lessees. The company employed an inspector to circulate among all leasing plants to insure uniformity of product. Efficiency Investigation, Joint Report, A.H. Tackett, J.P. Oren, "Consolidated File", 1, p. 5, Record Group No. 122, Federal Trade Commission, Bureau of Corporations, Numerical Files, 1903-14: Box No. 820, No. 7077-3-1. (National Archives)

[82] Efficiency Investigation, Part 3: Memorandum, p. 15 Record Group No. 122, Federal Trade Commission, Bureau of Corporations, Numerical Files, 1903-14: No. 7077-4-1, Box No. 820. (National Archives)

[83] NGB, 19 Nov. 1921; see also Robert Frink's claim that his design influenced the AWGC machine, and not vice-versa. "Frink Files Exceptions," NGB, 21 Sept. 1918.

suits claiming infringement on some aspect of the cylinder process. As early as 1907, it brought suit against Pittsburgh Plate Glass, James Chambers, Harry Slingluff and others, withdrew these in 1909 for unknown reasons, refiled them in 1914, and began actively pursuing them in 1918, by which time the courts looked unfavorably on their claims. The last suits, filed in 1924 against the Pittsburg Sheet Glass Company of Washington, Pennsylvania and others, were still in litigation when the AWGC itself replaced its Lubbers with Fourcault process machines. Two suits filed in 1914, against Consolidated subsidiaries in the Mountain District and the Okmulgee Window Glass Company in Oklahoma, established important legal grounds for the AWGC's position. Beside monetary damages and injunctions against operating competing processes, the opinions in these suits established the validity of the majority of the AWGC's patents, recognized the "new and useful" nature of its inventions, and defined their interdependence as "process," the grounds on which the company won the bulk of the remaining suits.[84]

The futility of such suits slowly became evident, as sheet drawing machines under development in the United States and Belgium sidestepped the AWGC's patent monopoly on mechanical cylinder-drawing methods. Drawing a flat ribbon of glass vertically from chambers attached directly to the tank, sheet methods transformed that part of the process giving the glass its shape but left intact mixing and melting the batch, and cutting and packing the finished product. Not only did the process eliminate blowers and gatherers, as did Lubbers, but it did away with flatteners as well, retaining cutters as the only skilled trade. Unlike the Lubbers process, which melted and shaped the glass in a series of discrete operations, sheet drawing was truly continuous from batch melting through shaping. Turning out large quantities of good quality glass, sheet drawing processes brought window glass into the era of continuous-flow mass production, rendering both hand and cylinder machine processes obsolete within a decade.

The two most successful sheet processes, the Colburn in America and the Fourcault in Belgium, had similar origins. Their inventors, Irving Colburn and Emile Fourcault, came out of engineering/mechanical backgrounds and had strong familial connections to the glass industry. This gave them a broad, conceptual approach to technical issues that answered the questions of drawing glass by machine not by resort to glass industry customs, but with a developing body of machine design principles and shop practices. Colburn was one of five brothers

[84]NGB, 2 Nov., 1918; 23 Nov., 1918; 30 Nov., 1908.

involved in the design and production of machine shop and glass making tools and equipment, the sons of Henry Colburn "an early mechanical engineer who apprenticed under Samuel Brown, the engineer of Boott Mills in Lowell, Massachusetts."[85] A shop-trained mechanic and engineer, Colburn invented a variety of electrical devices "such as dynamos, motors, platers, magnetos" in machine shops in Fitchburg, Massachusetts. In 1898, well before Lubbers had perfected his cylinder machine, Colburn and a backer, George Hoffman, claimed to have built the first sheet drawing machine in a factory in Philadelphia. Moving to Franklin, Pennsylvania, he carried on various experiments in his own factory and in the Star Glass Company in nearby Reynoldsville, finally obtaining a working model. Without the financial ability to continue development, Colburn's father exercised his long association with the Toledo glass interests and contacted Michael Owens, who purchased the process and perfected it over the next four years. By 1917, Libbey-Owens was constructing its first commercial window glass factory in Charleston, West Virginia, purportedly the largest in the world.[86] Like Colburn, Fourcault's family was connected to the glass industry; unlike Colburn, however, Fourcault "had a sound technical and scientific education, rather above the usual standard, at a Belgian and German Technical High School."[87] He worked as a mining engineer before becoming president of the Belgian Association of Master Glass Workers and Director of the Glass Works at Dampremy, where he carried on most of his sheet drawing experiments. Short of capital, he sold a portion of his patents to the International Plate Glass Union in 1910, but then continued during World War I, with German assistance, to developed unsold patent rights. By 1921, his process was successful enough for Jules Quertinmont, an American, to establish the American Fourcault Machine Company to distribute the machines in the United States.

Although they approached the problem in a similar fashion and faced many of the same obstacles, Colburn and Fourcault resolved the central problems of sheet drawn glass differently. Both sought to avoid the cylinder stage by drawing the sheet directly from the tank (or a chamber connected to it;) both encountered

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[85]Zembala, "Machines", p. 363.

[86]Colburn, George Louis. The Modern Method of Producing Continuous Sheet Glass. Quincy, MA: np, 1948; n.p.

[87]Max Muhling, "Notes on the Early Development of the Fourcault Process. The Development in Belgium," Journal of the Society of Glass Technology, XVII (1933), p. 145.

the problem of "traction...the gradual narrowing of the sheet" as it cooled.[88] Colburn's solution was a pair of water-cooled "knurl rolls" at the edges of the sheet, moving slightly slower than the speed of the draw and pointed downward to the outside, that pushed out the sides of the sheet to the desired width. Fourcault used a "debiteuse," an oblong "clay floater...shaped like a flat-bottomed boat. The bottom (had) a slit, with turned up sides, the tops of which" were submerged below the surface of the molten glass, thus forcing upward moderately viscous glass the width of the slit. Knurled rollers on the Fourcault machine complemented the "debi" in maintaining the edge until the glass hardened sufficiently.[89]

The two machines differed in other ways as well. Colburn and Owens wanted to produce a very strong glass; hence, the lehr on their machine measured approximately two hundred feet, substantially longer than any other in use. The lehr's length precluded a vertical draw, but experiments with a horizontal draw directly from the tank failed. Consequently, Colburn, Owens and others developed a system of cooling, reheating, bending and annealing the long sheet. An iron bar (bait) was dipped the tank's drawing chamber and pulled out vertically, with a two-inch thick molten glass ribbon attached. About two inches above the pool of glass, the knurled rolls grabbed and pushed out the sides of the sheet before two water-cooled bars stiffened it. At about three feet, the sheet was reheated by a gas flame and then bent ninety degrees over an iron roller to a horizontal plane for annealing. Glass was broken off in sheets at the end of the lehr run and taken to the cutting room for cutting and packing. Fourcault produced good quality glass by drawing vertically through a much shorter lehr (approximately twenty feet.) Breakers broke the glass off at the top of the machine and stacked it on bucks for transporting by means of skip hoist or elevator to the cutters.[90]

Sheet machine processes were far more efficient than those of

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[88]anon., "The Drawing of Sheet Glass," The Glass Industry, 2,8(August, 1921), p. 190.

[89]Ibid., pp. 190-3.

[90]J.B. Krak, "New Plant of the United States Sheet and Window Glass Company at Shreveport, Louisiana," The Glass Industry, vol. 3, no. 9(Sept., 1922); pp. 172-180; Ibid, vol. 2, no. 8(August, 1921); pp. 190-3.

hand or cylinder machines.[91] The Commissioner of Labor's opinion on the cylinder machine applied equally to hand production: "it is rather roundabout and requires much handling of the glass before the sheet finally reaches the cutting department.[92] As **Table 2** illustrates, in terms of both man-hour output and labor cost per box of glass, the Fourcault plants studied by the Commissioner enjoyed significant advantages over either cylinder method. Fourcault users had per-box labor costs less than one-third those of the hand industry and about seventy-five percent (single-strength) and forty percent (double-strength) those of cylinder machine producers. Yet, man-hour output of Fourcault plants was over one hundred sixty percent that of hand plants and thirteen percent greater than that of cylinder machine factories (single strength), while for double-strength, Fourcault surpassed hand made glass by one hundred twenty-eight percent and cylinder machine glass by nearly one-third.

Table 2

Index of Comparative Man-Hour Output and Per-Box Labor Cost, 1926*

	Single-strength		Double-strength	
hand production	100	100	100	100
cylinder machine	233.3	42.6	173.4	53
Fourcault machine	261.1	31.3	228.4	32.8

*Source: Adapted from U.S. Commissioner of Labor, Productivity of Labor in the Glass Industry. (Wash. DC: GPO, 1927), p. 159.

World War One and the brief prosperity that followed gave cylinder processes a new lease on life. Glass production prior to U.S. involvement surged as both domestic and foreign markets grew; between 1914 and 1917, the value of value of exports rose

[91] Unfortunately, Libbey-Owens declined to furnish the Labor Department with production statistics for its rigorous 1927 study Productivity of Labor in the Glass Industry. Figures were made available for Fourcault, cylinder machine, and hand processes (Washington, DC: GPO, 1927).

[92] Dept. of Labor, Productivity,, p. 161.

from $311,339 to $3,483,596.[93] Higher prices naturally attracted additional hand and machine manufacturers.[94] (See **Appendix A**) Once the U.S. entered the war, the War Production Board classified window glass as a "nonessential" industry, established an industry-wide output ceiling of fifty percent of 191? production, and evenly allocated fifty percent of total output between hand and machine sectors. For hand manufacturers and workers, this was an increase of twenty-five percent of their 1916 output. Following the war, the glass industry set record output levels as domestic construction and exports surged. Hand and cylinder machine glass makers benefitted from the combination of war-stimulated demand and the guarantee of market share during the conflict, to some extent neutralizing the impact of the 1917 startup of the Libbey-Owens Colburn-machine plant at Charleston, West Virginia.

By the mid-twenties, sheet processes were adding market share at the expense of both hand and cylinder machine manufacturers, as **Table 3** illustrates. In 1917, Libbey-Owens opened its massive Charleston, West Virginia plant. Costing $1.5 million initially, the plant was enlarged in 1920 and again in 1923, when its capacity rose to eighteen Colburn machines and represented more than $7 million in invested capital. The company also established an additional plant in Hamilton, Ontario, Canada and leased its machines to the United States Sheet and Window Glass Company of Shreveport, Louisiana.[95] In 1921, Belgian glass blower, cooperator and factory owner Jules Quertinmont organized the American Fourcault Machine Company of Point Marion, Pennsylvania, to import and lease Fourcault machines in the United States. Quertinmont himself installed the first Fourcault machines east of the Mississippi in his Fairchance, Pennsylvania plant.[96] The onslaught of sheet drawing machines decimated the ranks of hand process manufacturers and skilled workmen. The hand sector accounted for forty percent of domestically-made

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[93]U.S. Tariff Commission, The Glass Industry as Affected by the War. (Washington, DC: GPO, 1918), p. 22.

[94]Scoville suggests higher prices perhaps overstated the extent of the industry's prosperity just prior to U.S. involvement, persuading Libbey-Owens to accelerate the opening of their Charleston plant. Scoville, Revolution, p. .

[95]NGB, 20 Nov. 1920.

[96]The National Glass Company of Shreveport, Louisiana was the first to use Fourcault machines in the United States, but the plant later burned.

window glass in 1916, but only two percent a decade later.

Table 3

Window Glass Production, by Process, 1900 - 1935*
(percent)

Year	Hand Cylinder Process	Machine Cylinder Process	Sheet Drawing Process
1900	100	0	0
1904	95	5	0
1910**	50	50	0
1916	40	60	0
1919	25	65	10
1923	10	52	38
1926	2	59	39
1929	0	20	80
1932	0	5	95
1935	0	0	100

*Source: Harry Jerome, Mechanization in Industry.
**Data for 1910 from C&GW,

By 1928, the AWGC realized its cylinder drawing process was no longer commercially viable. In output quality and quantity, sheet machine plants surpassed those making glass by the cylinder process, and did so with lower production costs as well. In 1924, the AWGC was forced to install secondary flattening ovens to remove the slight bow imparted to the glass by the cylinder method. Other defects, such as burn marks from flattening blocks, were more difficult, if not impossible to remedy, giving sheet glass a clear superiority.[97] The loss of the best, most lucrative markets drove the AWGC to search out niches where it might not have to compete against sheet glass, for example, by introducing a "fourth quality" glass at a rate below "B" prices to "compete with poor quality imports."[98] In 1925-6, the company suffered its first operating loss "since the prewar years," posting a deficit of $381,550 at the same time that Libbey-Owens recorded profits of over $2.7 million. The

[97] Min., AWGC, 1 Nov., 1924. (Taken from AWGC annual report.)

[98] C&GW, 5 Nov., 1921.

following year, losses climbed to over $2.3 million. Although the lower costs of sheet machine companies led the AWGC to drop its prices and pass on similar reductions to its cutters and flatteners, the company found, to its dismay, "that such a cut would result in a saving of only thirty-eight cents on the price of a box of glass. Labor alone," AWGC president and general manager William Loftus Monro admitted, "cannot bear the brunt of lessened costs...."[99] In February, 1928 at its Belle Vernon, Pennsylvania plant, the AWGC began replacing its Lubbers process with Fourcault machines, and the following year announced a complete corporate reorganization.[100]

The transition to the Fourcault sheet drawing method did little to help the AWGC's precarious financial condition in the face of the Great Depression. Nearly breaking even in 1928-9, the company lost over $.5 million the following year and nearly three times that in 1930-1. It closed all but its Belle Vernon and Arnold plants for most of the depression, and did not reopen Jeannette until 1936. By that time, the industry had assumed the corporate and technological styles it would retain for the next forty years, with the AWGC ranking third after Libbey-Owens-Ford and Pittsburgh Plate Glass in window glass production.

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[99] C&GW, 18 June, 1921.

[100] C&GW, 4 Feb., 1928; 6 Oct., 1928; 1 June, 1929. It is of interest that the AWGC had an experimental Fourcault machine at its Arnold plant as early as 1913. Unfortunately, records do not reveal the activities of the company with this process. AWGC documents, inventory.

Appendix A

Average Gross Selling Price for 50′ Box Window Glass

Year Ended August 31	Price/ 50′ box
1900	$2.39
1901	3.09
1902	2.93
1903	3.22
1904	2.23
1905	1.69
1906	1.82
1907	1.95
1908	1.63
1909	1.53
1910	2.00
1911	1.76
1912	1.47
1913	2.11
1914	2.29
1915	2.27
1916	2.32
1917	3.37
1918	4.39
1919	5.81
1920	5.98
1921	5.66
1922	4.01
1923	3.90

*Source: American Window Glass Company, Average Gross Selling Price for 50′ Box Window Glass, c. 1924, from archives, AWGC.

Appendix B

Lubbers Cylinder Machine Development

The transition from hand to machine production confronted Lubbers and his colleagues with a formidable array of technical obstacles in the melting, expanding, drawing and take-down stages. Tank design and function at that time prevented glass from being drawn from the main chambers of the tank itself; glass had to be sluiced into a forehearth or ladled into separate pots. In either method, the bath from which the cylinder was drawn had to be uniform in temperature or the cylinder would travel to the hottest areas, become uneven and possibly break from the uneven surface tension. But both methods radiated the bath's heat from exterior walls, making the temperature higher at the center and progressively cooler to the outside. Resolving this problem by adding more heaters to the forehearth and pots produced a further difficulty, making the glass too hot to set properly once the draw had begun. To increase its viscosity Lubbers devised a shield to protect the cylinder from the bath's heat and a water-cooled collar that floated on the bath's surface and symmetrically cooled the glass as it was drawn. Choice of receptical also presented complications. The forehearth was the most attractive alternative because of the ease of moving the molten metal from the tank. But cooled glass remaining in the forehearth after the draw (called aftermath) mixed poorly, if at all, with new glass entering the forehearth. Similar problems plagued the process of ladling glass into single pots. Lincoln Thornburg solved this issue with a double-reversible pot. Resembling two shallow pans connected at their exterior bottoms, glass was drawn from the top pot as the aftermath was cleaned from the downward-facing pot by the constant play of gas-fueled flames. Cullet was returned to the doghouse by conveyor.[101]

Cylinder expansion presented a different set of difficulties. As in the hand process, machine-made cylinders required the injection of air into the cylinder to achieve the desired diameter. Precisely how to do so--upward through the pot, by stationary tube removed following the draw, or through a pipe at the head of the cylinder--was finally resolved in favor of the blow-pipe. Only after much experimentation did Lubbers realize that a gradually increasing, rather than a uniform, supply of air would produce a cylinder consistent in diameter over its entire length. The relatively small amount of air pressure needed to

[101]NGB, 23 Nov., 1918; Linton, Window Glass Machine, 11.

expand the cylinder--approximately four-tenths of an ounce per square inch--prompted Lubbers to develop a finely graduated valve calibrated to the speed of the draw. But the valve failed to correct a tendency of the cylinder to "breathe" during the forming stage, producing bumps and corrugations that flawed the glass. Although he finally eliminated this characteristic by venting the closed air system, two decades of further research failed to reveal the source of the "breathing" or why the vent stopped it. In addition to bumps and corrugations, he experienced a persistent problem with "thick and thin" glass, where slightly cooler parts of the bath caused cylinder wall circumference to vary in thickness. Improvements in ladling, uniformity in heating Thornburg pots, and protecting the bath from drafts of cool air helped reduced this problem, but could not eliminate it. Consequently, Lubbers positioned the bait at the point of average viscosity and allowed the cylinder to move as that point shifted during the draw. Elongating the cylinder required raising the iron bait (to which the molten glass attached) to the optimal length. Gearing and line shafting, the power-transfer mechanisms of choice in early twentieth century industry, allowed the glass to cool and grow stiffer and thicker as the draw proceeded. Chambers himself developed a graduated conical winding drum to replace the gearing and substituted a cable for the line shafting, thereby increasing the speed of the draw by imperceptible increments, while Harry Hitner invented a hand rheostat to electrically control the entire operation.[102]

As various innovations increased the size of the cylinders produced by the Lubbers process, their handling and processing became serious concerns. Take-down, as it was called, involved detaching the cylinder from the blowing and drawing machinery and lowering it to floor level. Lubbers developed a detachable air hose connecting blowpipe and air supply and learned, after much experimentation, that the most effective method for detaching the cylinder from the drawing machinery and lowering it to the floor was to leave the heavy iron blowpipe and bait attached to the cap of the cylinder. When the cylinder reached the appropriate height, the air supply was first slowed and then stopped, thinning cylinder walls at the pot, where the cylinder itself was easily broken free. An asbestos fork was then placed around the cylinder base and the cable, blowpipe and cylinder lowered to a set of horses. The horses, invented by John Bridge, consisted of a series of connected but independently moving cradle arms onto which the large cylinder was lowered. The arms were so arranged as to facilitate the division of the long cylinder into smaller

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[102] NGB, 23 Nov., 1918.

sections for flattening.[103]

[103]Ibid.